



Exploration EVA Virtual Collaboration Event

August 16, 2018

9am-12pm CDT



Exploration EVA Virtual Collaboration Event

Chris Hansen, EVA Office Manager

August 16, 2018



Welcome!



- Overall Goal today ... to communicate!
 - The last time we gathered the EVA technology community was in October of 2017
- What is today about?
 - At every workshop we solicit feedback and last year we received several comments on timing of our workshops, as a result we have decided to shift the next workshop to February of 2019
 - Today's virtual event can be considered a pre-cursor to that workshop ... we hope to accomplish at least 2 objectives
 1. Solicit help in planning for EVA Technology Workshop in 2019
 2. Provide the community an update on EVA Exploration flight and technology development that has occurred since October 2017
- We invite your input
 - Please submit your questions to:
 - jsc-eva-exploration-workshop@mail.nasa.gov



Planning for the 2019 Workshop



- When: February 19-21, 2019
- Where: Johnson Space Center-Gilruth Facility (Houston TX)
- What: 2-3 Day interactive event, with thoughts of both NASA led day(s) and an Industry led day



xEMU: Progress Update Follow-up from October 2017

Brian Johnson, Exploration EVA Office Lead

August 16, 2018



xEMU: Progress Update




- The agency's EVA development plans and implementation are well grounded and moving forward!
 - ✓ NASA will use the existing EMU through at least 2024 for ISS operations, with possible modifications and updates to continue risk reduction and increase safety for the ISS crew.
 - ✓ NASA will demonstrate and test key exploration components on orbit using the ISS as a testbed.
 - ✓ NASA will pursue a phased approach to explore EVA capability from LEO through cislunar space to the surface of Mars.
- A key component of this plan is the development of the Exploration EMU (xEMU) for flight on ISS
 - Project is proceeding on schedule (more to come on this)
- Objective of this presentation is to ...
 - Provide a summary of the programmatic story of how the xEMU Demonstration plan was created
 - Provide a backdrop for the development of the “xEMU standard” that will be discussed in next presentation



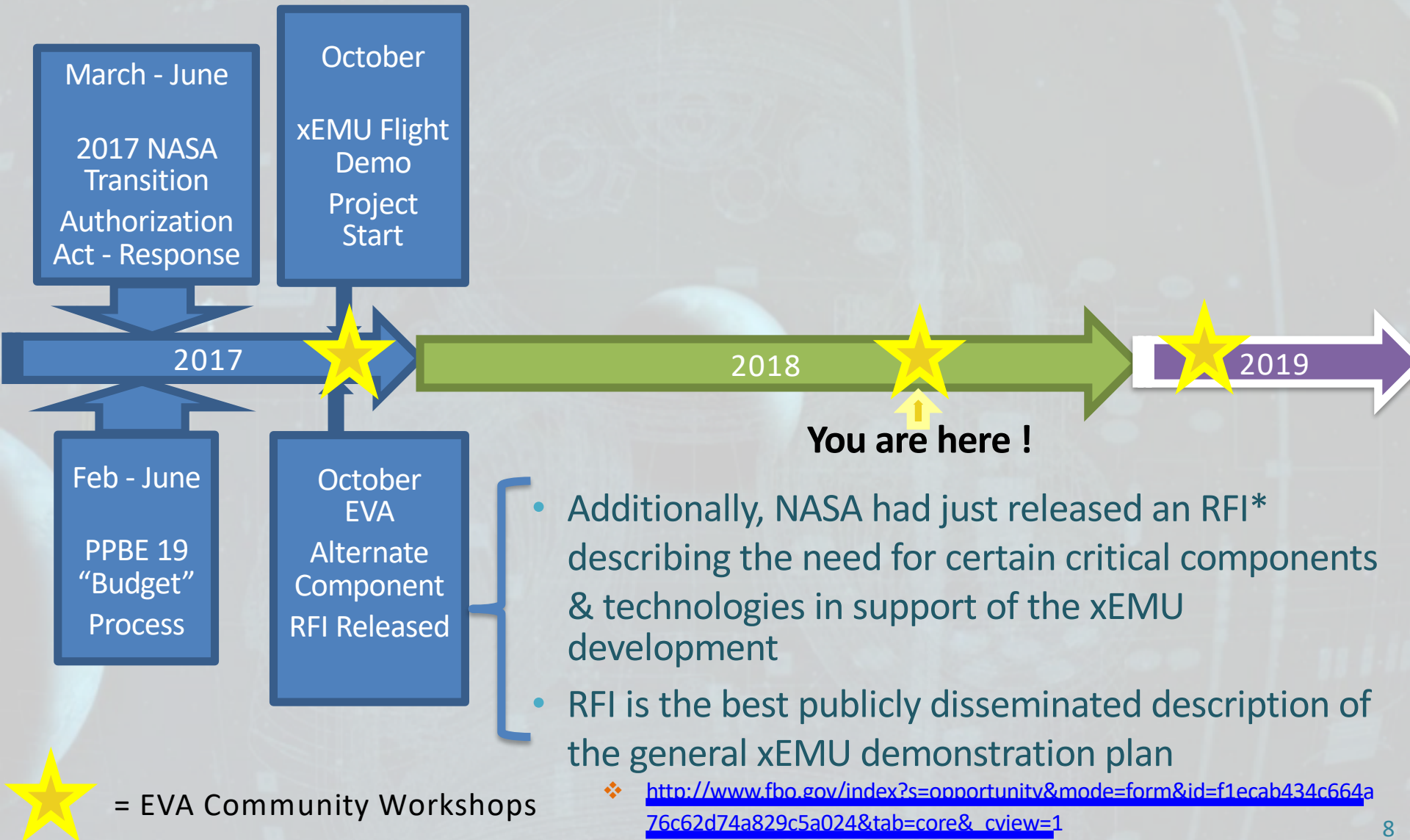
EVA Development Planning and Programmatic Timeline



 = EVA Community Workshops

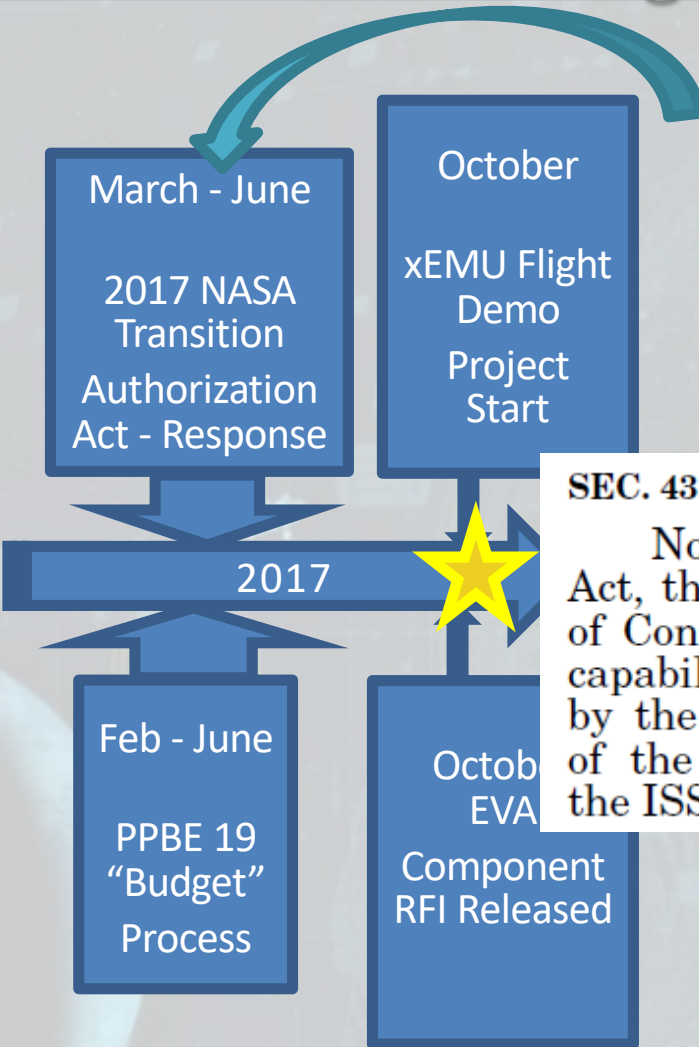


EVA Development Planning and Programmatic Timeline





EVA Development Planning and Programmatic Timeline



- The initiation of the xEMU demo project and the RFI were founded on plans developed for Congress in the spring of 2017
 - Response to a congressional actions in the 2017 NASA Transition Authorization act

SEC. 433. ADVANCED SPACE SUIT CAPABILITY.

Not later than 90 days after the date of enactment of this Act, the Administrator shall submit to the appropriate committees of Congress a detailed plan for achieving an advanced space suit capability that aligns with the crew needs for exploration enabled by the Space Launch System and Orion, including an evaluation of the merit of delivering the planned suit system for use on the ISS.

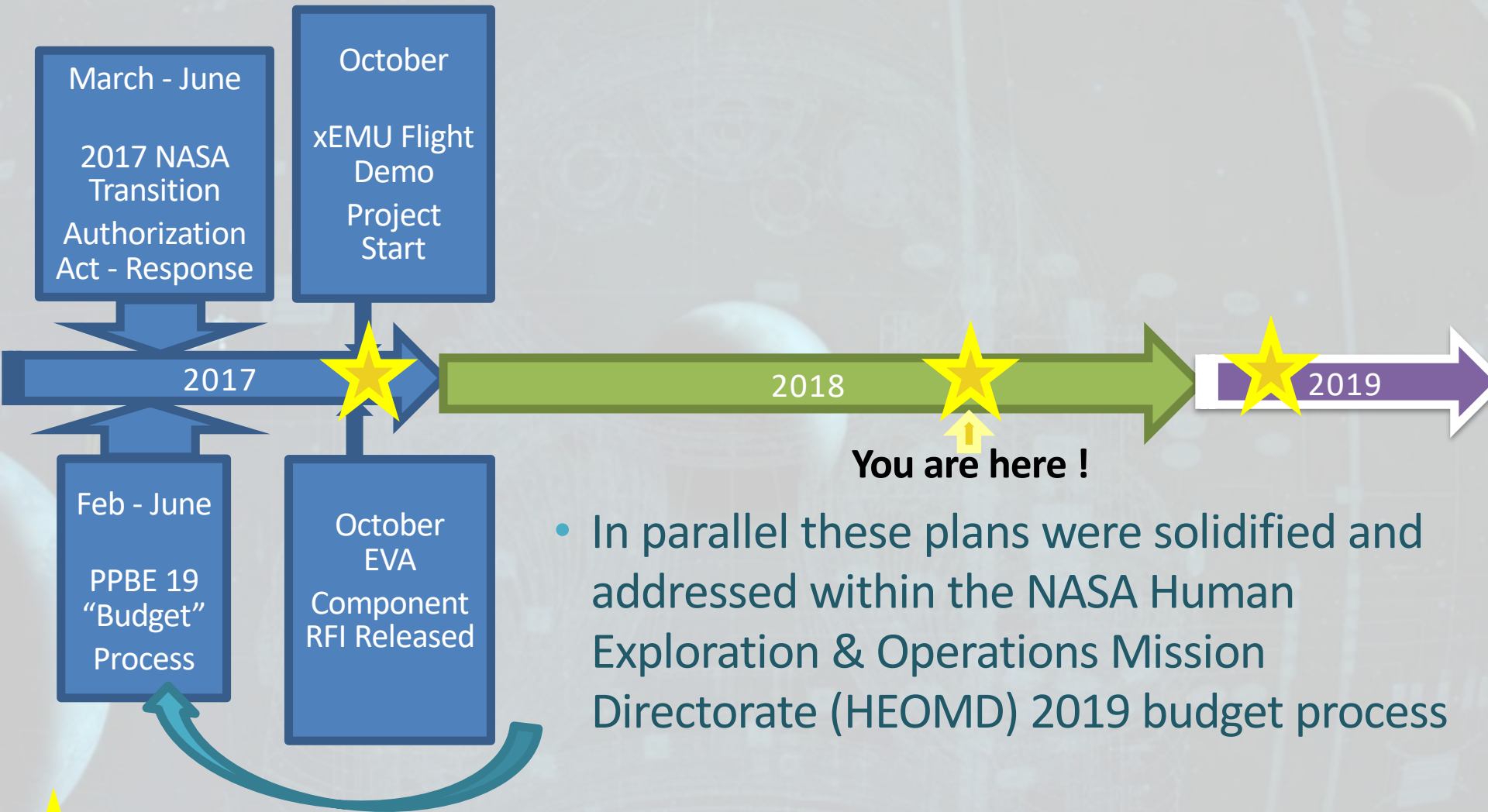
- It is within this plan that we introduce the idea of an “xEMU Standard” as the ultimate product of the flight demonstration project



= EVA Community Workshops



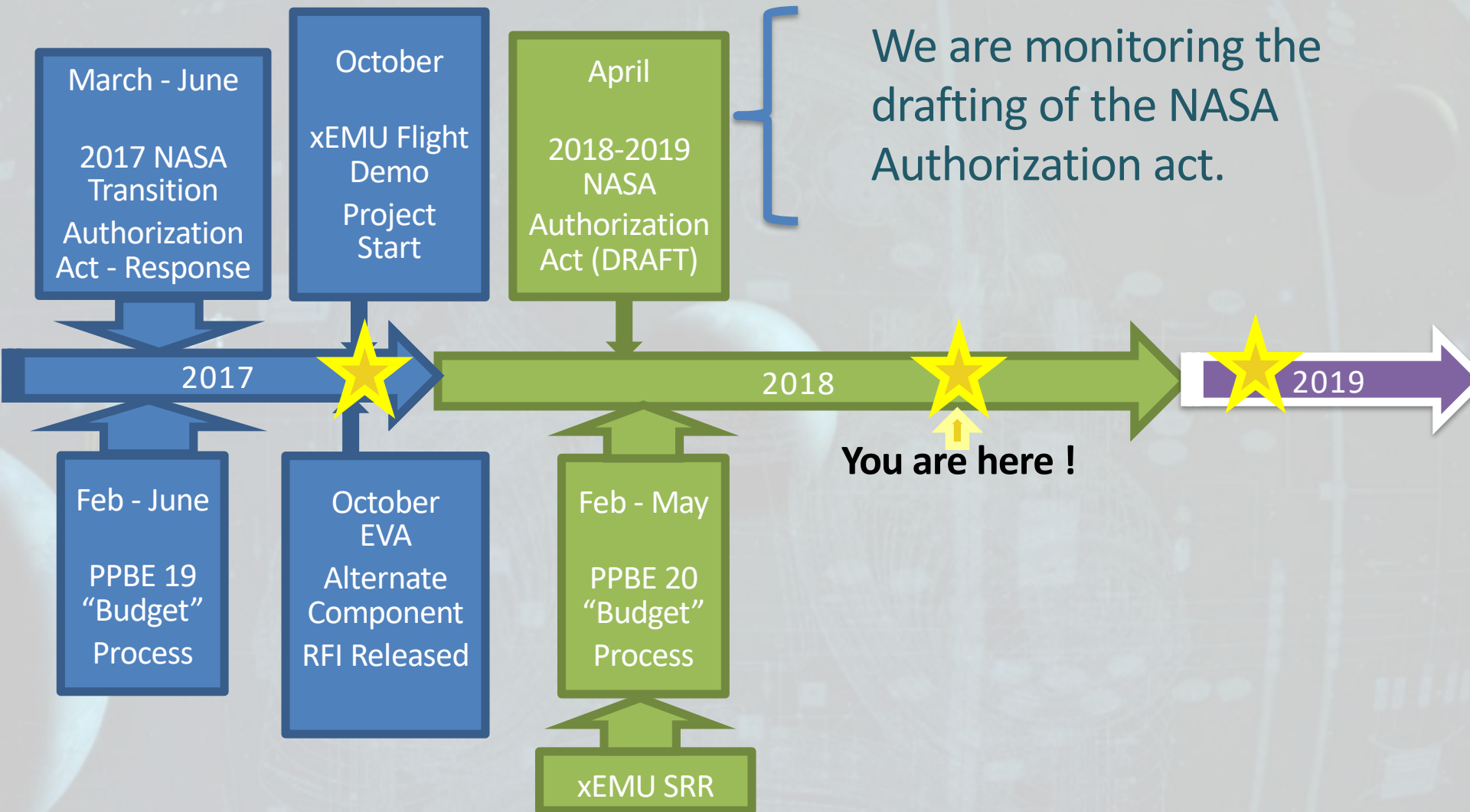
EVA Development Planning and Programmatic Timeline



 = EVA Community Workshops

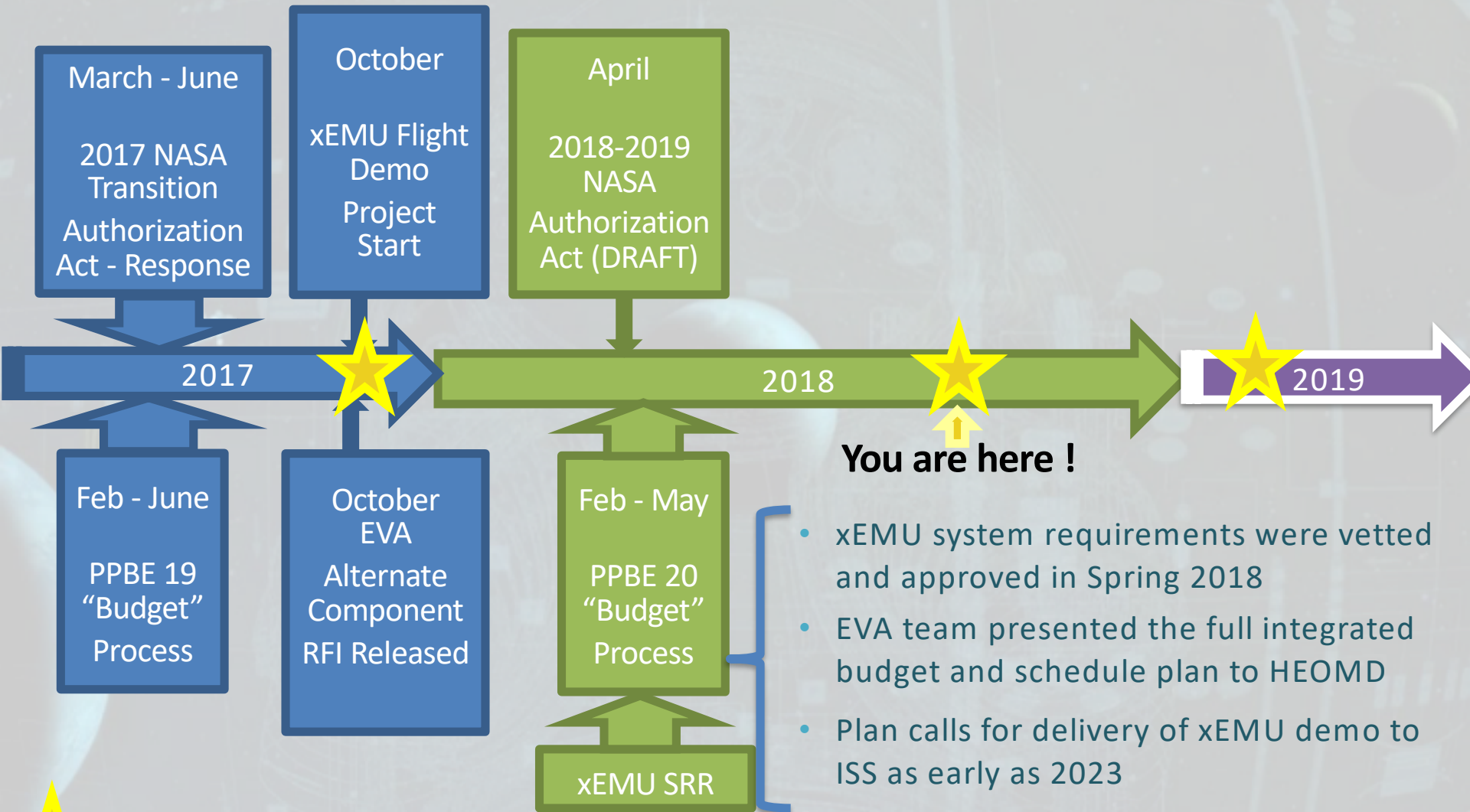



EVA Development Planning and Programmatic Timeline





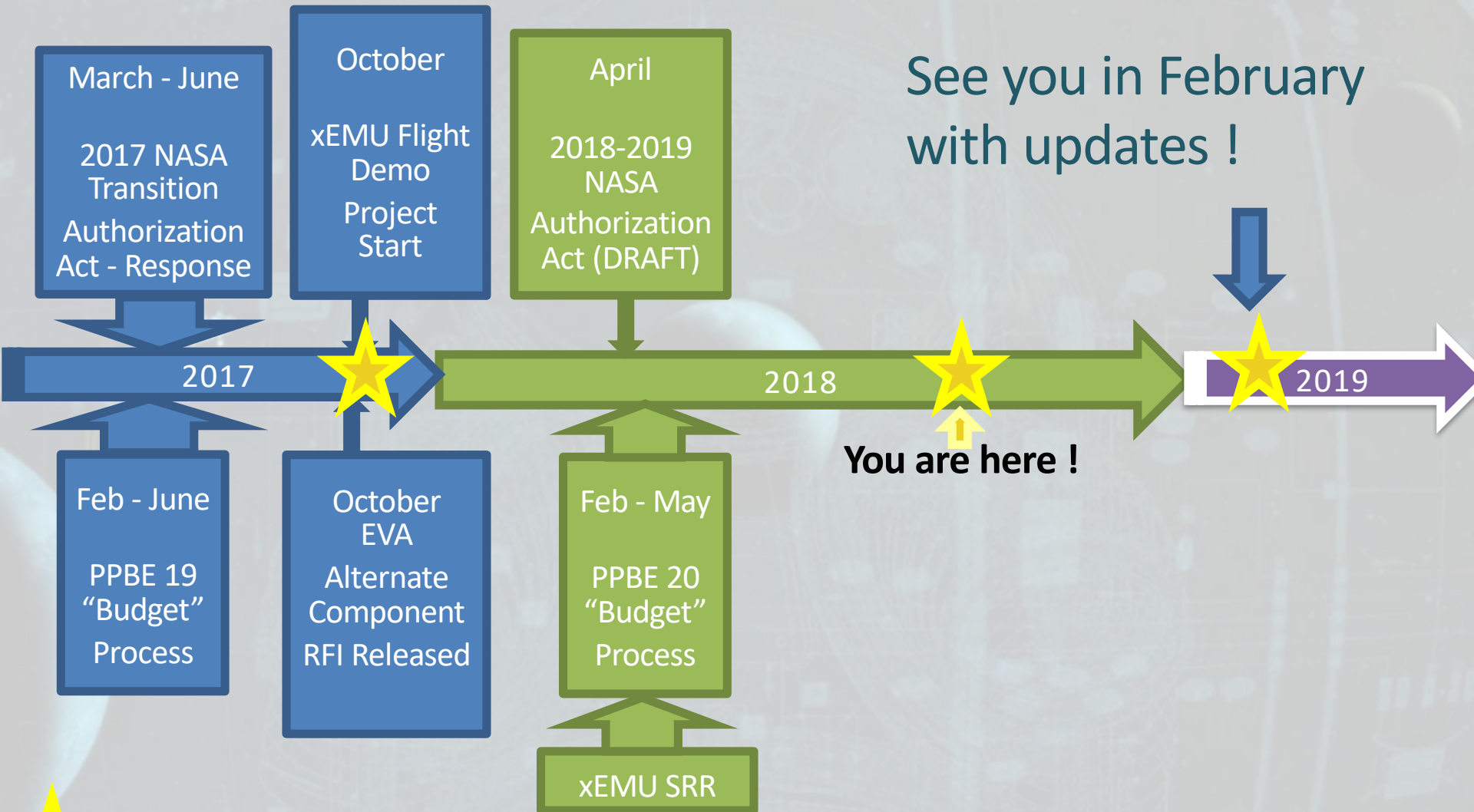
EVA Development Planning and Programmatic Timeline




 = EVA Community Workshops



EVA Development Planning and Programmatic Timeline



 = EVA Community Workshops



Progress Wrap up ...



- EVA community has a solid plan going forward for flight demonstration of an advanced exploration spacesuit
 - Based on years of technology development provided by industry and academia
- In addition to solidifying planning for the xEMU project, NASA has renewed its efforts to communicate all that we can and to engage our industry partners
 - Today's event!
 - Planning for February Workshop
 - Involving suppliers in xEMU Demo technical reviews
 - Working as fast as we can to disseminate data publically given the need to conform to export control regulations
 - We are assessing what is the “xEMU Standard” as well as the how & when do we disseminate this data



xEMU: Progress Update ***From Specification to Standards***

Jesse Buffington, xEVA System Development Lead

August 16, 2018



The xEVA Standard: Purpose



- The “xEVA Standard” is a concept that facilitates capture and communication of NASA’s xEMU specification
- Development of the xEVA Standard will proceed in parallel with the development of the xEMU ISS Demo Suit hardware
- NASA has a range of options for what level of detail is published in the Standard
- Successful demonstration of the xEMU on ISS provides *validation* that there is at least one way the Standard can be met

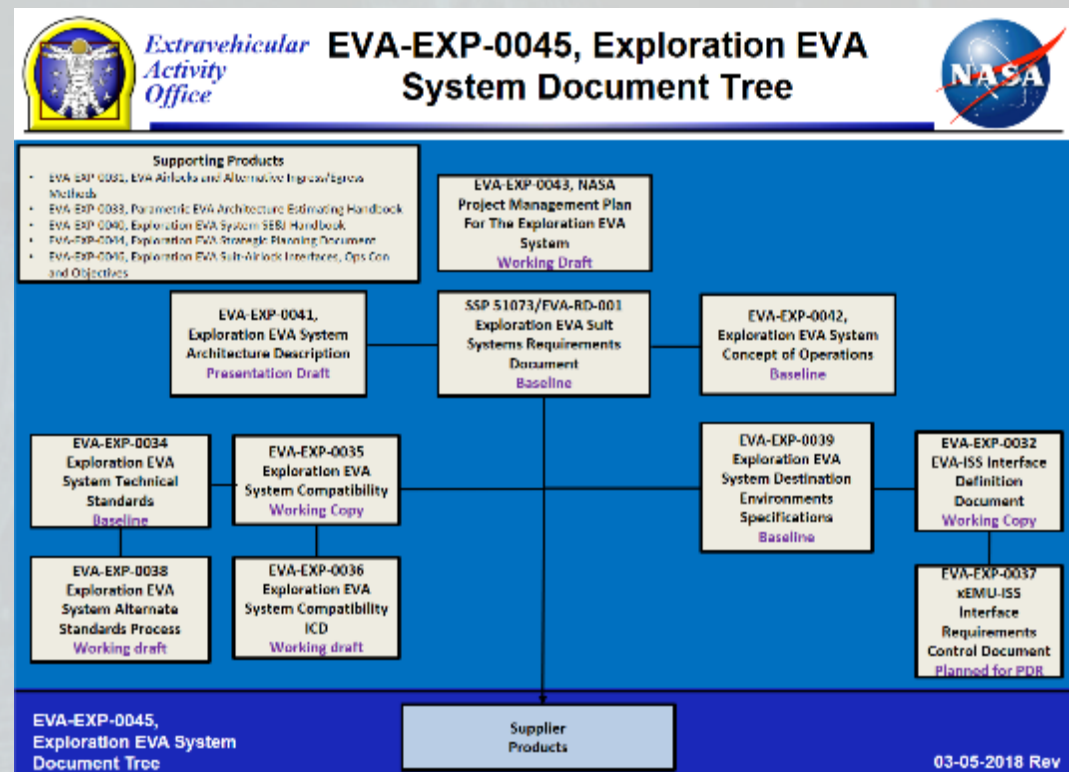




The xEVA Standard: Supporting Materials



- The xEVA Standard will likely include portions of the Exploration EVA System Document Tree
- The EVA Office has initiated processing many of these products and posts each as the Document Availability Authorization (DAA) process is completed
- Similar to the design of the xEMU, the xEVA System Document Tree products will continue to evolve

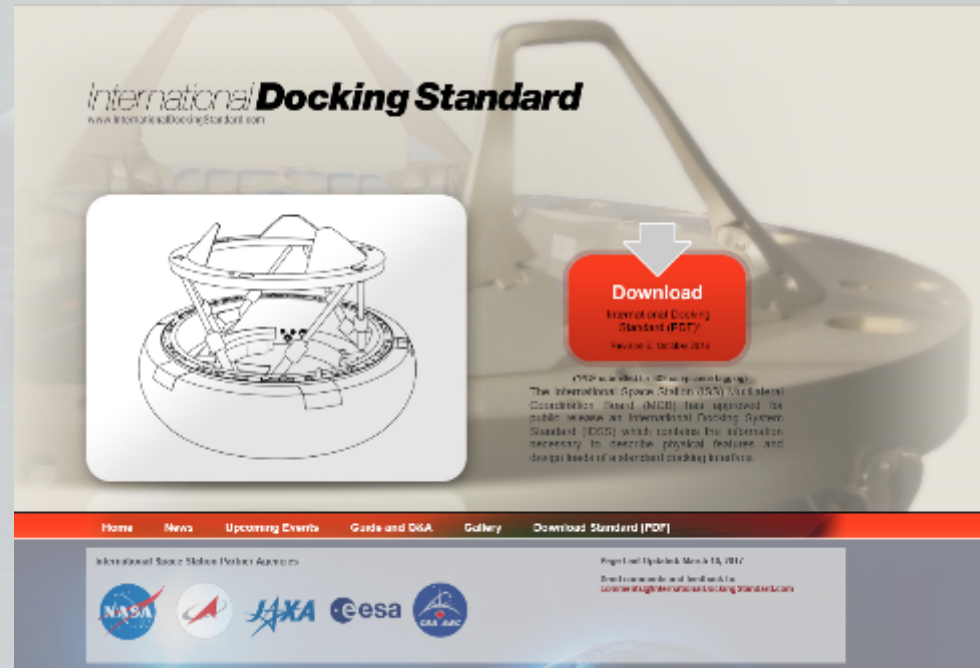




NASA Standards: Recent Examples



- There are several relevant examples within current NASA activities which provide precedence for an xEVA Standard
- NASA may take an approach similar to the International Docking System Standard (IDSS) which is publicly posted:
 - The IDSS IDD includes performance characteristics of the system such as OML/SWAP/Functions
 - The IDSS IDD heavily emphasizes the interfaces and component features allowing two separately built docking collars to join as intended



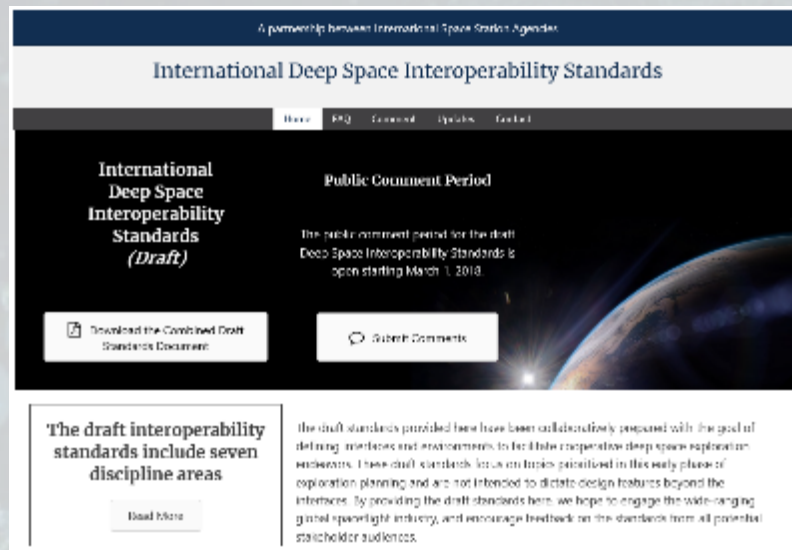
<http://www.internationaldockingstandard.com/>



NASA Standards: Recent Examples



- Similarly, work underway with NASA and international partners includes interoperability standards for vehicle elements and systems:



<https://www.internationaldeepspacestandards.com/>

- These examples and many others are available to NASA for xEVA
- The xEVA team will be exploring each of these over the next several years to determine which model is best for xEMU



The xEVA Standard: Next Steps



- The xEVA team is evaluating several options for structure, depth of detail and review process for the Standard
- In general, the Standard will progress with the xEMU Design
- It's likely that the Standard will be revised (similar to IDSS) over time as NASA further matures xEMU for various missions
- Supporting xEVA products are and will continue to be posted, see: www.nasa.gov/suitup/reference
- At the Workshop in February, we'll further discuss and seek feedback on the process for developing the Standard, plans for draft review and comment from the community, etc





xEMU Development Status

Liana Rodriggs, xEMU Project Manager

August 16, 2018



xEMU Development Overview



- The Exploration Extravehicular Mobility Unit (xEMU) Project objective is to develop an xEMU for a flight demonstration on ISS
 - The xEMU Demo suit will be designed to meet as many of the exploration requirements as feasible within cost and schedule constraints
- The NASA team that has been performing EVA technology development for 10+ years is designing the xEMU Demo and will build a single flight demonstration unit
 - NASA will be procuring components and will perform the role of system integrator
- Major milestones are shown in the table below working towards a flight demonstration on the ISS in 2023

FY18	FY19	FY20	FY21	FY22	FY23
SRR (Jan)	PDR		CDR		SAR & Delivery
DVT Build/Assy		DVT Testing	Qual & Flight HW Build		Acceptance Testing
				Qual Testing	

Terms and Definitions: SRR – System Requirements Review, PDR – Preliminary Design Review, CDR – Critical Design Review, DVT – Design Verification Testing, SAR-Systems Acceptance Review



Development Status



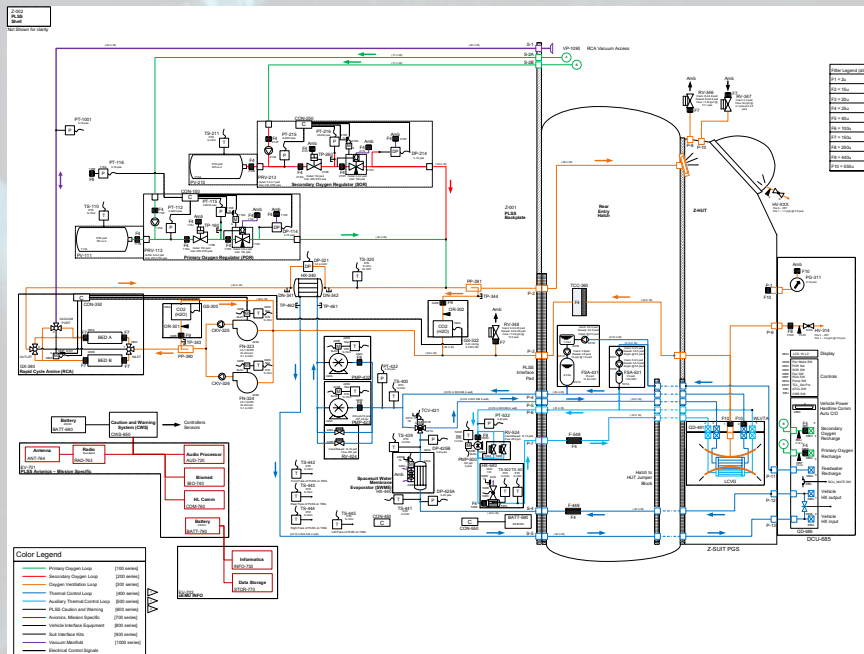
- System Requirements Review and Phase 0 Safety Review were completed earlier this year
 - Review focused on Project Technical Requirements Specification, EVA-ISS Interface Definition Document, Concept of Operations, ISS Demo Objectives, Safety Data Package, and Initial Assessment of Criticality with dozens of supporting documents available for reference
 - Completion of SRR set the requirements for what will be included in the demonstration and what is deferred to future development efforts
- Team is focused on preparations for PDR and DVT hardware build/test
 - xEMU DVT hardware will be the implementation of the requirements set during SRR
 - DVT will be tested as a “qualification dry run” and will provide data to mature design towards CDR
 - Buys down risk of building qual and flight units in parallel
- Component and system-level designs continue to mature – sampler of technical progress on next slides



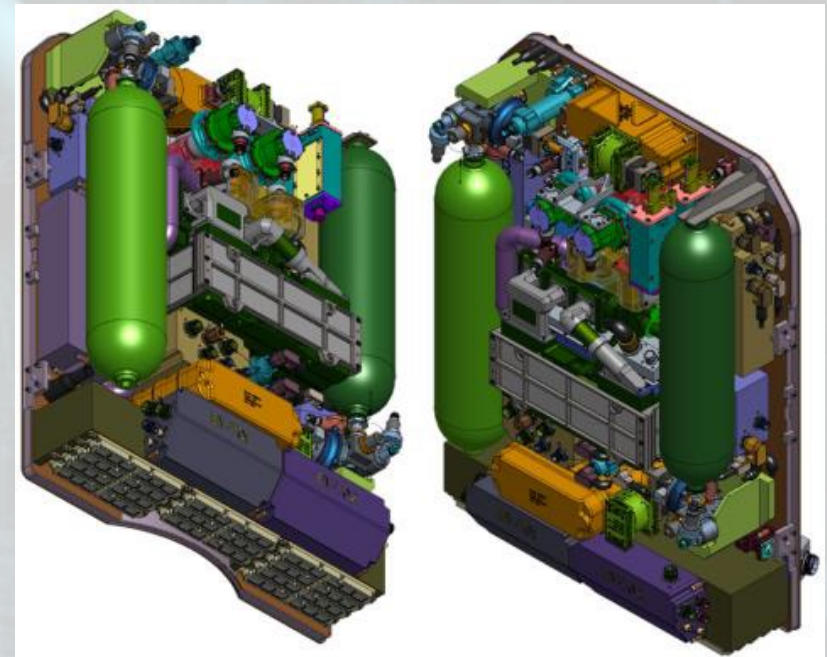
Hardware Development Update



- Conducted a 2 ½ day Technical Interchange Meeting to status the design of the Portable Life Support Subsystem (PLSS)
 - Included review of components and subsystem-level design and analyses and status of progress towards Preliminary Design Review (PDR)
 - PLSS packaging update completed just prior to review to modify package size and shape and incorporate other improvements



PLSS Schematic



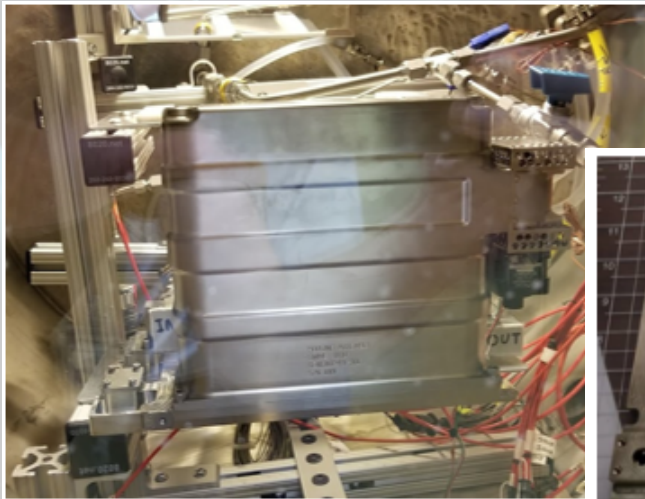
PLSS Packaging



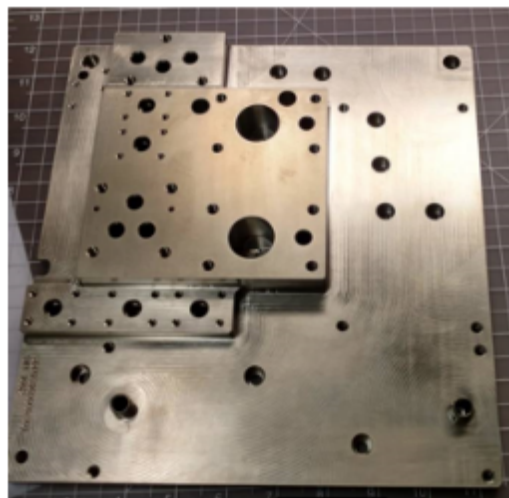
Hardware Development Update



- Completed over 400 hours to-date, of a planned 800 hours of life testing of the Suit Water Membrane Evaporator (SWME)
- Evaluated manufacturing techniques for the PLSS backplate and manufactured pathfinder
- Tested an alternate CO₂ Swing Bed System to evaluate performance characteristics



**SWME 800 Hour Test
In Progress**



Backplate Pathfinder



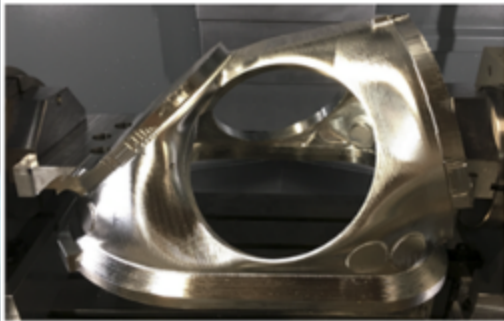
CO₂ Swing Bed System Testing



Hardware Development Update



- Updated design of Hard Upper Torso (HUT) and helmet to incorporate lessons learned from last year's NBL testing
 - Procured updated HUT and helmet, along with waist adapter ring and visor assembly for assembly into Z-2.5 for NBL testing later this year
- Designed test methodology for manloads testing and completed hand grasp breakaway evaluations for upcoming testing



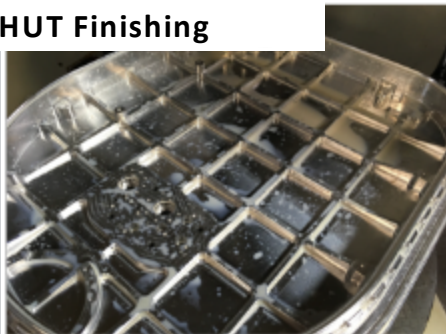
Z-2.5 HUT Finishing



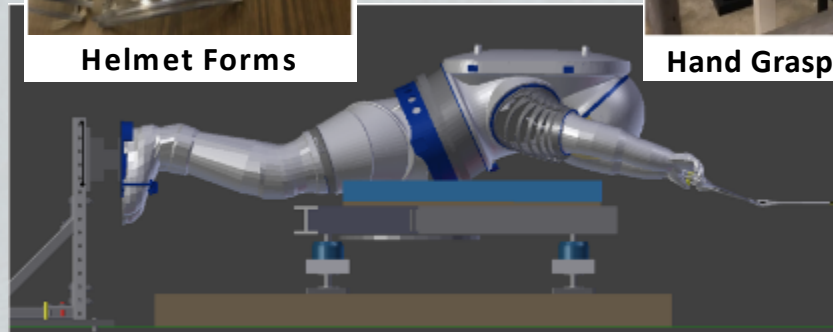
Helmet Forms



Hand Grasp Breakaway Evaluation



Z-2.5 HUT Hatch



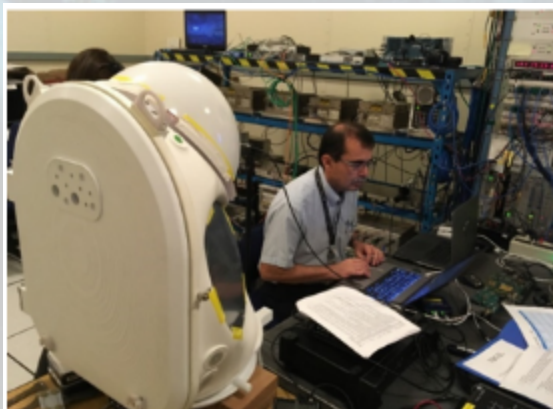
3D Rendering of the Full Suited Manloads Test



Hardware Development Update



- Performed Integrated Communication System (ICS) testing to evaluate susceptibility of ICS to produce acoustic feedback when connected to ISS audio system
- Performed suited evaluation of Environmental Protection Garment (EPG) sleeve concepts
- Modified a prototype Liquid Cooling and Ventilation Garment (LCVG) to add a redundant cooling loop and conducted fit-check with 3D printed Z-2.5 HUT



**Integrated Communications Testing
Z-2.5 3D Printed HUT**



**Range-of-Motion Evaluation of Different
EPG Sleeve Concepts**



Modified Prototype LCVG



Looking ahead



- More details will be presented at the EVA Workshop in February, such as:
 - Update on technical progress
 - Major risks
 - Schedule
 - Objectives and approach to demonstration EVA's
- Other developments are occurring in parallel that will feed into the xEMU such as the EVA Data Recorder (EDaR) development
- Beyond the xEMU Demonstration, additional development is needed to fully realize all of the exploration capabilities of the xEMU in support of future missions



The Road Ahead

Brian Alpert, EVA Strategic Planning and Architecture Lead

August 16, 2018



The Road Ahead: ISS Demo



EVA Technology and EMU Upgrades

On-orbit ISS - 2018

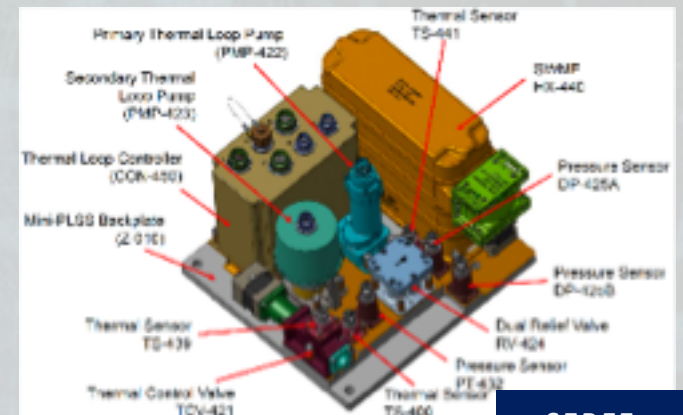
- Umbilical Interface Assembly (UIA):
Incorporates support recharging of higher pressure EVA suit oxygen bottles.
- Long Life Battery 2 (LLB-2):
Advanced Lithium-Ion batteries incorporate the latest safety features.
- EVA Data Recorder (EDaR):
Added to the EMUs to enable high-speed recording of all critical sensor data.



LLB-2

FY19 Delivery:

- Spacesuit Evaporation Rejection Flight Experiment (SERFE):
xEMU thermal system as a payload.
- High-definition EVA Camera Assembly (HECA):
Upgrade for EMU and the baseline camera set for the xEMU.



SERFE



The Road Ahead: ISS Demo



- xEMU Flight Demonstration - 2023
 - Test objectives: Reviewed at SRR, baselining post PDR
 - Will perform EVAs (1 EMU and 1 xEMU Demo)
 - Finalizing test plan; expect multiple EVAs over months on ISS
 - Lessons Learned
- After ISS Demo ... branching out options
 - xEMU as continued option with EMU (depends on ISS life) to develop standards
 - Support for commercial opportunities to develop their own capabilities
 - xEMU for Gateway



xEMU Demo



The Road Ahead: Cis-Lunar Space



- NASA is working with Commercial and International partners on plans to expand human presence into Cis-Lunar space
- NASA is studying a Gateway mission with the objective to build a human-tended space station parked in lunar orbit
 - Notionally this space station would be visited by a crew of up to 4 for up to 30 days at least once per year
- EVA and Airlock objectives can be found in released documents
 - “Lunar Orbital Platform – Gateway Management Directive” (DSG-MD-10000)
 - “Human Exploration and Operations Exploration Objectives” (HEOMD-001)



xEMU



The Road Ahead: Cis-Lunar Space



- Implementation of the Gateway mission has matured tremendously in the past year
 - Finishing up 2nd Integrated Analysis Cycle in August
 - Preparing for Formulation Sync Review in September 2018 (System level requirements)
 - Power and Propulsion Element (PPE) request for proposal has been released (acquisition)
- EVA concepts in Gateway
 - Airlock launches at end of sequence: All external work is via robotics until Airlock arrives; no capsule-based EVA
 - Carrying EVA-specific requirements (Exploration EVA System Compatibility, module specific, no requirements for PPE)
- EVA engagement with Gateway
 - EVA team working with Gateway on establishing program (Level 2) requirements and element functional allocations
 - Working Airlock requirements and interfaces, external interfaces, and crew rescue capability
 - Working with Habitat Broad Agency Announcement study teams
 - Working with International Partners via the International Exploration Capability Study Team





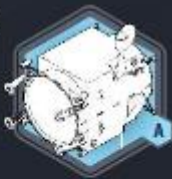
Gateway Overview



GATEWAY An exploration and science outpost in orbit around the Moon

Power and Propulsion Element:

Power, communications, attitude control, and orbit control and transfer capabilities for the Gateway.



ESPRIT:

Science outpost, additional propellant storage with refueling, and advanced lunar telecommunications capabilities.



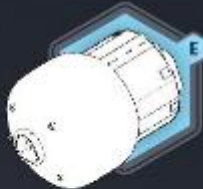
Utilization Element:

Small pressurized volume for additional habitation capability.



Habitation Modules:

Pressurized volumes with environmental control and life support, fire detection and suppression, water storage and distribution.



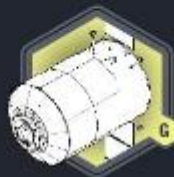
Robotic Arm:

Mechanical arm to berth and inspect vehicles, install science payloads.



Logistics and Utilization:

Cargo deliveries of consumables and equipment. Modules may double as additional utilization volume.



Airlock:

Enables spacewalks, potential to accommodate docking elements.



Sample Return Vehicle:

A robotic vehicle capable of delivering small samples or payloads from the lunar surface to the Gateway.



NASA-led architecture and integration

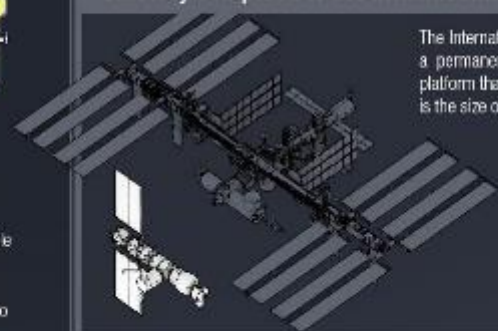


Orion:

U.S. crew module with ESA service module that will take humans farther into deep space than ever before.



Gateway Compared to the International Space Station



The International Space Station is a permanently crewed research platform that has 11 modules and is the size of a football field.

The Gateway is a much smaller, more focused platform for extending initial human activities into the area around the Moon.



The Road Ahead: Lunar Surface



- NASA recently vocal about shifting focus towards lunar exploration missions as a stepping stone towards Mars, as well as engaging commercial and international partners going forward
 - US Space Policy Directive -1: “... will refocus America’s space program on... returning American astronauts to the Moon... for long-term exploration and use”
- System-level Exploration EVA Requirements encapsulate Lunar Surface needs
 - To the best of our knowledge we have captured requirements in “Exploration EVA Suit Systems Requirements” (SSP 51073/EVA-RD-001)
 - Knowledge gaps remain:
 - ISS xEMU Demo suit will not invoke all Cis-Lunar and Lunar Surface requirements ... extensibility actions in work and due at PDR in 2019
 - Goal is to truly understand the challenges to upgrading the xEMU Demo technologies

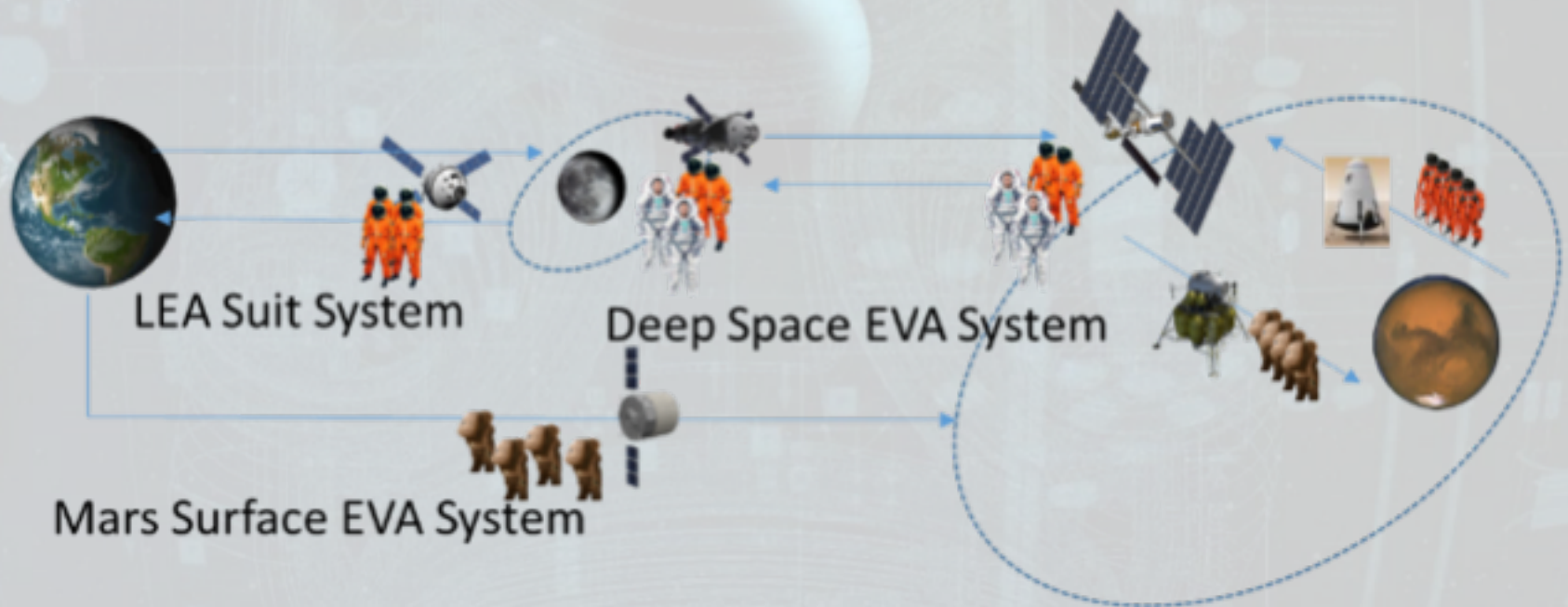




The Road Ahead:Mars



- Engaging with Mars Study Capability team, supporting concept of operations studies, and supporting analog mission research
- Identifying technology and knowledge gaps towards development of EVA capabilities for Mars Surface ops





EVA Technology Gaps

Raul Blanco, *Chief, Space Suit and Crew Survival Systems Branch*
August 16, 2018



Motivation



- NASA needs industry and academia help in closing gaps
- Communicating our needs and priorities with you:
 - Gives businesses an opportunity to direct IR&D towards NASA stated priorities
 - Gives academia an opportunity to direct research in areas that are relevant to NASA stated priorities
 - Helps SBIR proposers understand more context on why the annual EVA subtopics are chosen
 - Decreases our likelihood of missing a gap



Current Schedule Based Gap Closure Priorities



1. Support ISS EVA through life of program
 - Use ISS as a testbed
2. Complete development of the Orion Crew Survival System (OCSS) as to support Exploration Mission 2 (EM-2) schedule
3. Leverage xEMU demo and develop technologies to support complete xEMU readiness for Gateway
4. Invest in enabling technologies for a potential Lunar surface mission
5. Invest in long development time enabling and enhancing technologies to enable mEMU





February Workshop Plans



- Update to NASA HEOMD-001 Exploration Phases and resulting high level suit architecture (if any)
- Detail of gaps between xEMU ISS Demo and xEMU for Gateway
- High level summary of key gaps between xEMU ISS Demo and xEMU for lunar surface mission
- High level summary of key gaps for xEMU to mEMU
- Walk through of either on-line gap tool or through newly published data file



BACK UP



Gateway Development



GATEWAY DEVELOPMENT

Establishing leadership in deep space and preparing for exploration into the solar system

FOUNDATIONAL GATEWAY CAPABILITIES

2022

2023

2024+



50 kW-class
Power &
Propulsion
Element

Habitation
and
Utilization

Logistics and
Robotic Arm

Airlock

These foundational gateway capabilities can support multiple U.S. and international partner objectives in cislunar space and beyond.

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CAPABILITIES

- Supports exploration, science, and commercial activities in cislunar space and beyond
- Includes international and U.S. commercial development of elements and systems
- Provides options to transfer between cislunar orbits when uncrewed
- External robotic arm for berthing, science, exterior payloads, and inspections

OPPORTUNITIES

- Logistics flights and logistics providers
- Use of logistics modules for additional available volume
- Ability to support lunar surface missions

INITIAL SCOPE



4 Crew Members



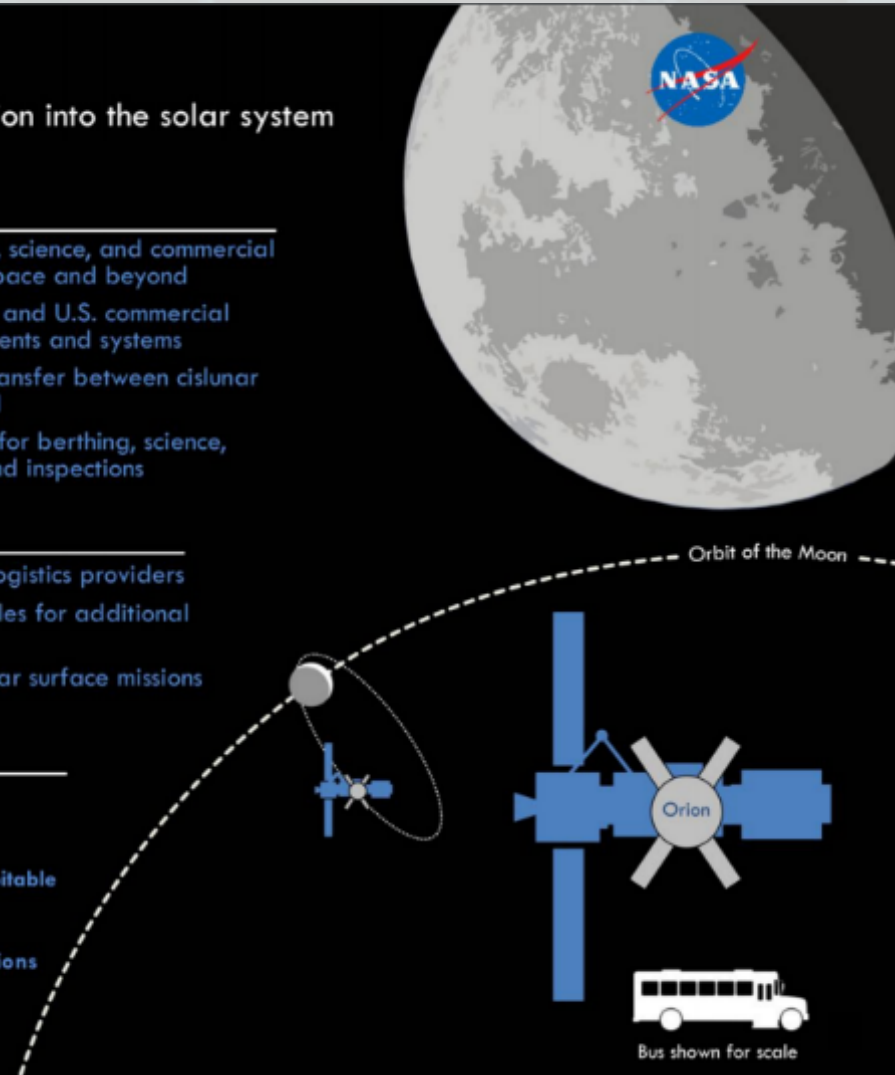
At least 55 m³ Habitable Volume



30 Day Crew Missions



Up to 75mt with Orion docked



Bus shown for scale



Exploration EVA System Document Tree



Supporting Products

- EVA-EXP-0031, EVA Airlocks and Alternative Ingress/Egress Methods
- EVA-EXP-0033, Parametric EVA Architecture Estimating Handbook
- EVA-EXP-0040, Exploration EVA System SE&I Handbook
- EVA-EXP-0044, Exploration EVA Strategic Planning Document
- EVA-EXP-0046, Exploration EVA Suit-Airlock Interfaces, Ops Con and Objectives

**EVA-EXP-0043, NASA
Project Management Plan
For The Exploration EVA
System**
Working Draft

**EVA-EXP-0041,
Exploration EVA System
Architecture Description**
Presentation Draft

**SSP 51073/EVA-RD-001
Exploration EVA Suit
Systems Requirements
Document**
Baseline

**EVA-EXP-0042,
Exploration EVA System
Concept of Operations**
Baseline

**EVA-EXP-0034
Exploration EVA
System Technical
Standards**
Baseline

**EVA-EXP-0035
Exploration EVA
System Compatibility**
Working Copy

**EVA-EXP-0039
Exploration EVA
System Destination
Environments
Specifications**
Baseline

**EVA-EXP-0032
EVA-ISS Interface
Definition
Document**
Working Copy

**EVA-EXP-0038
Exploration EVA
System Alternate
Standards Process**
Working draft

**EVA-EXP-0036
Exploration EVA
System Compatibility
ICD**
Working draft

**EVA-EXP-0037
xEMU-ISS
Interface
Requirements
Control Document**
Planned for PDR

**EVA-EXP-0045,
Exploration EVA System
Document Tree**











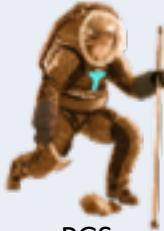

**Supplier
Products**

03-05-2018 Rev



Suit Architecture



Configuration	Pressure Garment	Life Support	Description
 <p>Orion Crew Survival Systems (OCSS)</p>	 <p>OCSS suit</p>	 <p>Umbilical</p>	<p>Orion Crew Survival Systems (OCSS) includes the LEA-optimized suit and associated survival systems hardware being delivered to Orion. (Current EC GFE project; PDR summer 2017)</p>
 <p>Exploration Extravehicular Mobility Unit (xEMU)</p>	 <p>xPGS</p>	 <p>xPLSS</p>	<p>xEMU is the dedicated EVA suit system for use on the Gateway stack to demonstrate EVA capability and then serve as the in-transit EVA suit for Mars missions.</p>
 <p>Exploration Extravehicular Mobility Unit with Lunar kit (xEMU-L)</p>	 <p>xPGS-L</p>	 <p>xPLSS</p>	<p>xEMU with minimal upgrades (such as TMG and dust tolerant connectors) and delta certification could serve as the system for surface EVA for Lunar missions. (minimal tech dev required for TMG materials and dust mitigation)</p>
 <p>Mars Extravehicular Mobility Unit (mEMU)</p>	 <p>mPGS</p>	 <p>mPLSS</p>	<p>mEMU is a Mars environment optimized, highly mobile EVA suit (based on xEMU), for missions up to 500 days on surface. (tech dev required for materials and PLSS function in partial atmosphere)</p>